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(71) Applicant(s)
Clevis Fulcrum Limited

(Incorporated in the United Kingdom)

Gorst Hall, Staindrop, DARLINGTON, Co Durham, DL2 3LD, United Kingdom

(72) Inventor(s)
Nicholas James Korbey

(74) Agent and/or Address for Service
Clevis Fulcrum Limited
Gorst Hall, Staindrop, DARLINGTON, Co Durham, DL2 3LD, United Kingdom

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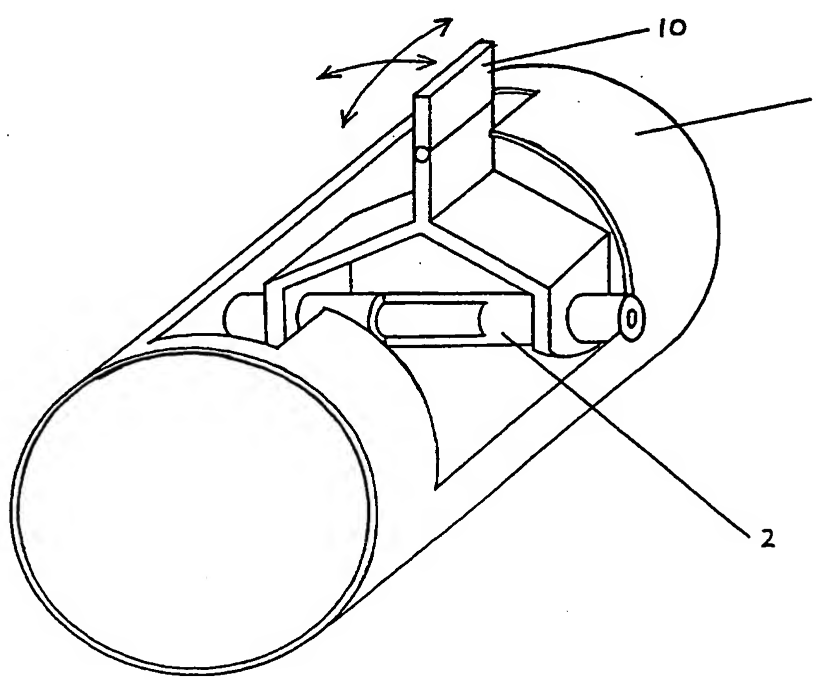
(54) Controlling the azimuth and elevation of a towed object

(57) A control unit, including a computer, measures and resolves towline azimuth and elevation relative to a drone. These data are used in real time to control surfaces such as a pair of wings or vanes that are attached to the drone. These controlled surfaces afford the operator significantly more control over the position of the drone, both vertically and horizontally, relative to the towline and tractor. Consequently the controlled flight envelope of the drone is considerably enlarged by this invention. Furthermore, improved access to, and simpler construction o, the internal workings of the drone are enabled, as well as the reduction of bearing loads. The towline is connected to the drone by a universal shackle 10, and details of control logic used are disclosed.

FIGURE I



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This is a reprint to rectify errors introduced in the course of reproduction-Figs. Page 8/8 added-15.12.1997

FIGURE I

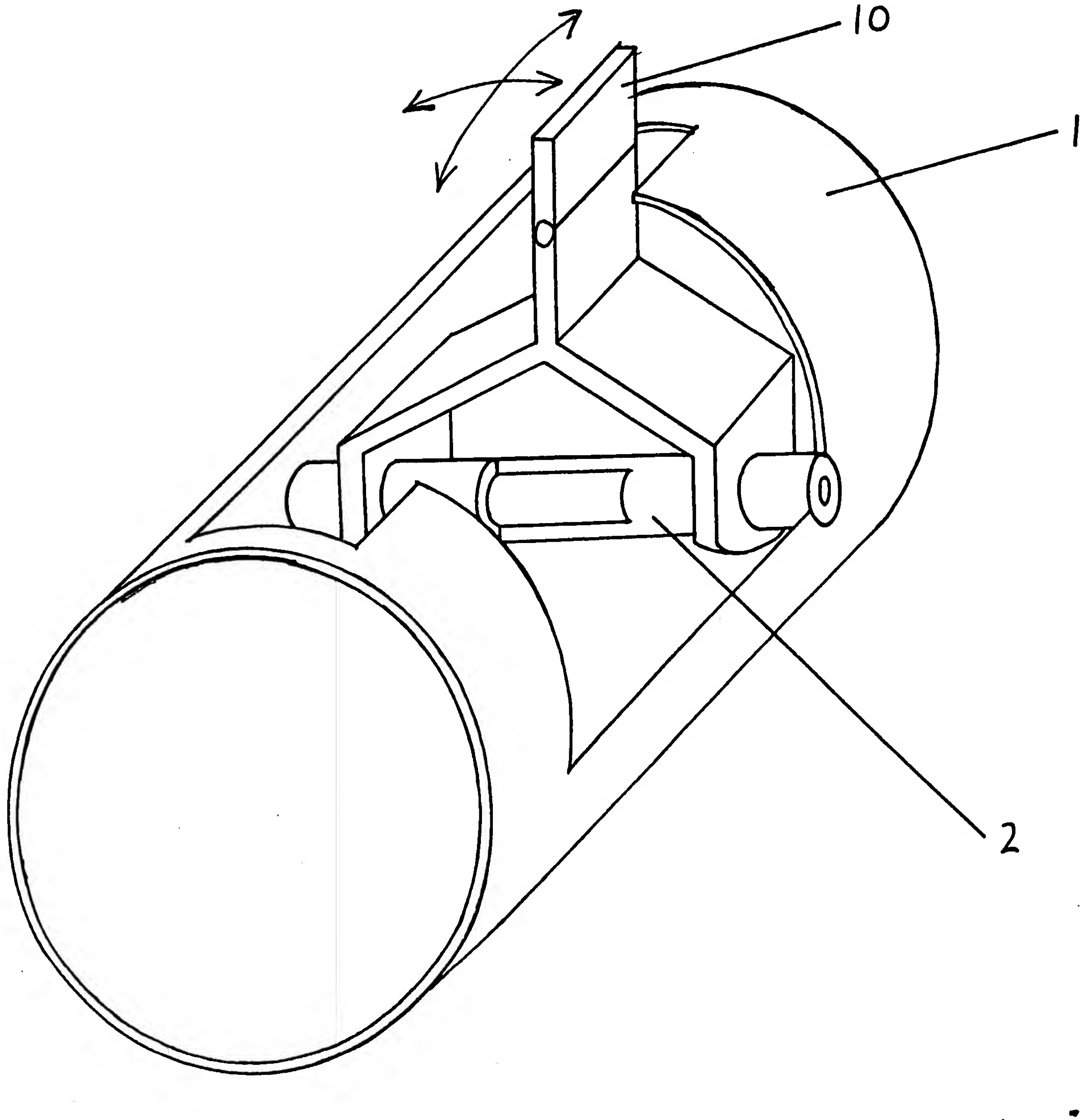

FIGURE II

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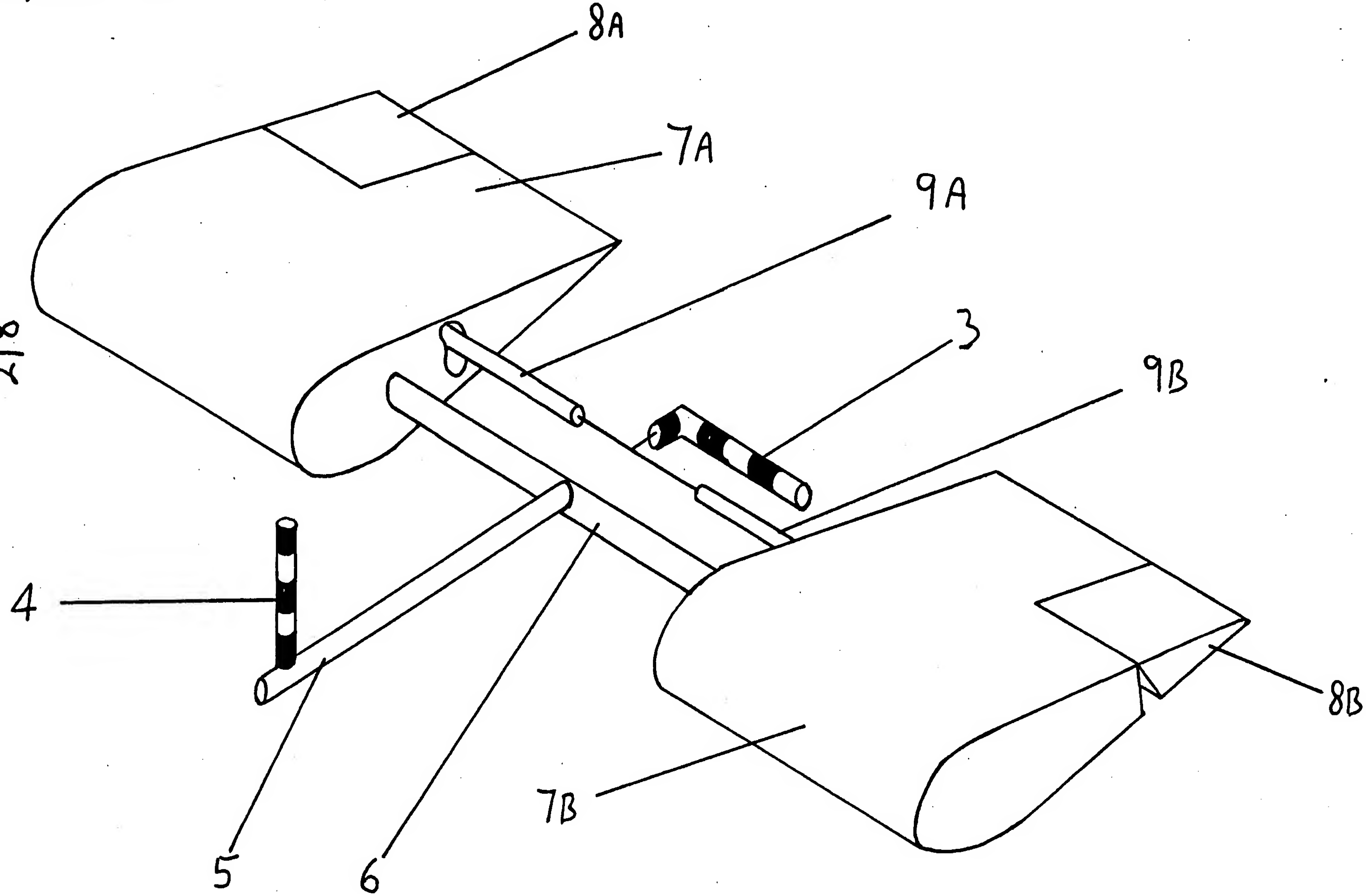

FIGURE III

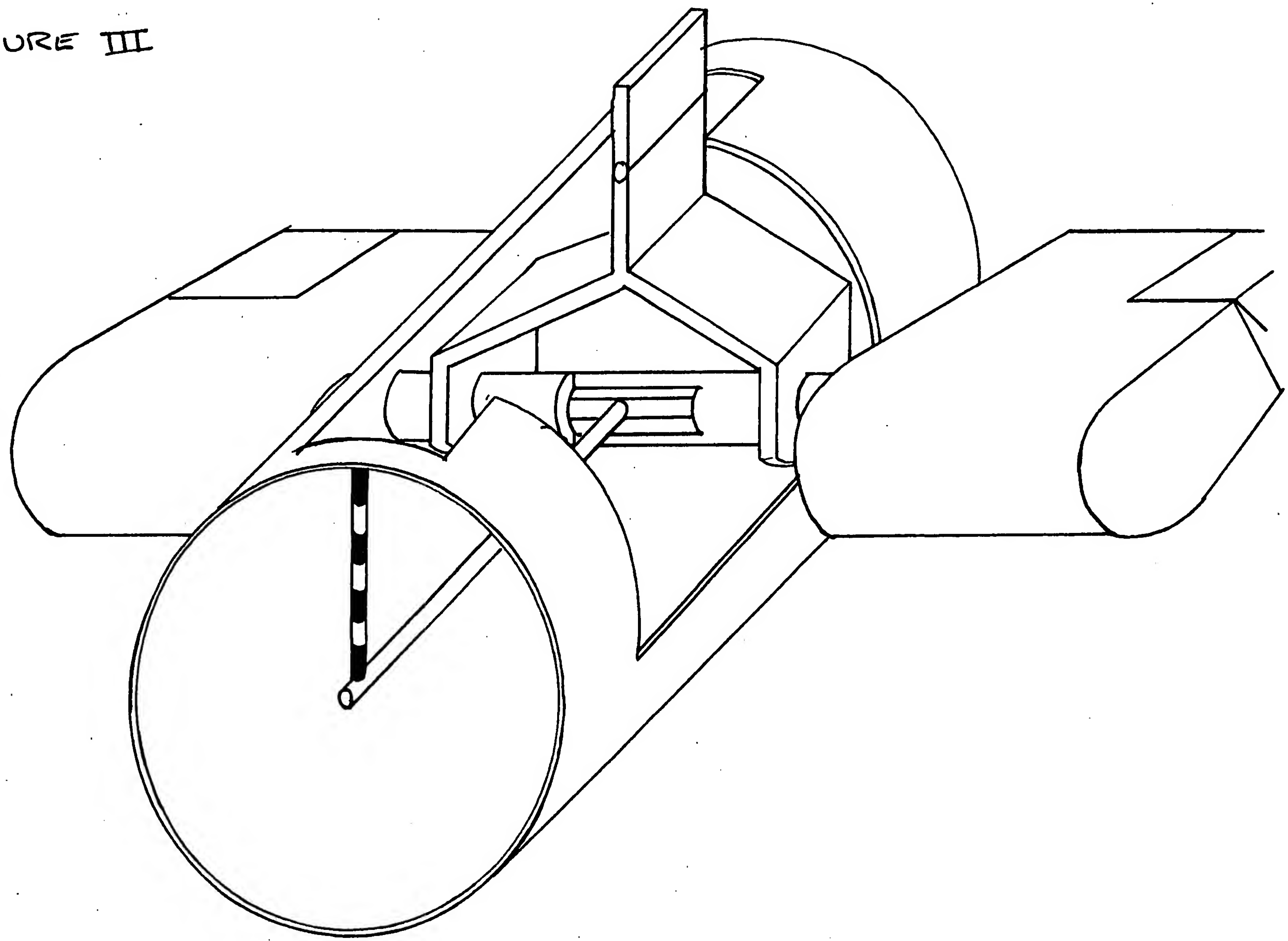

FIGURE IV

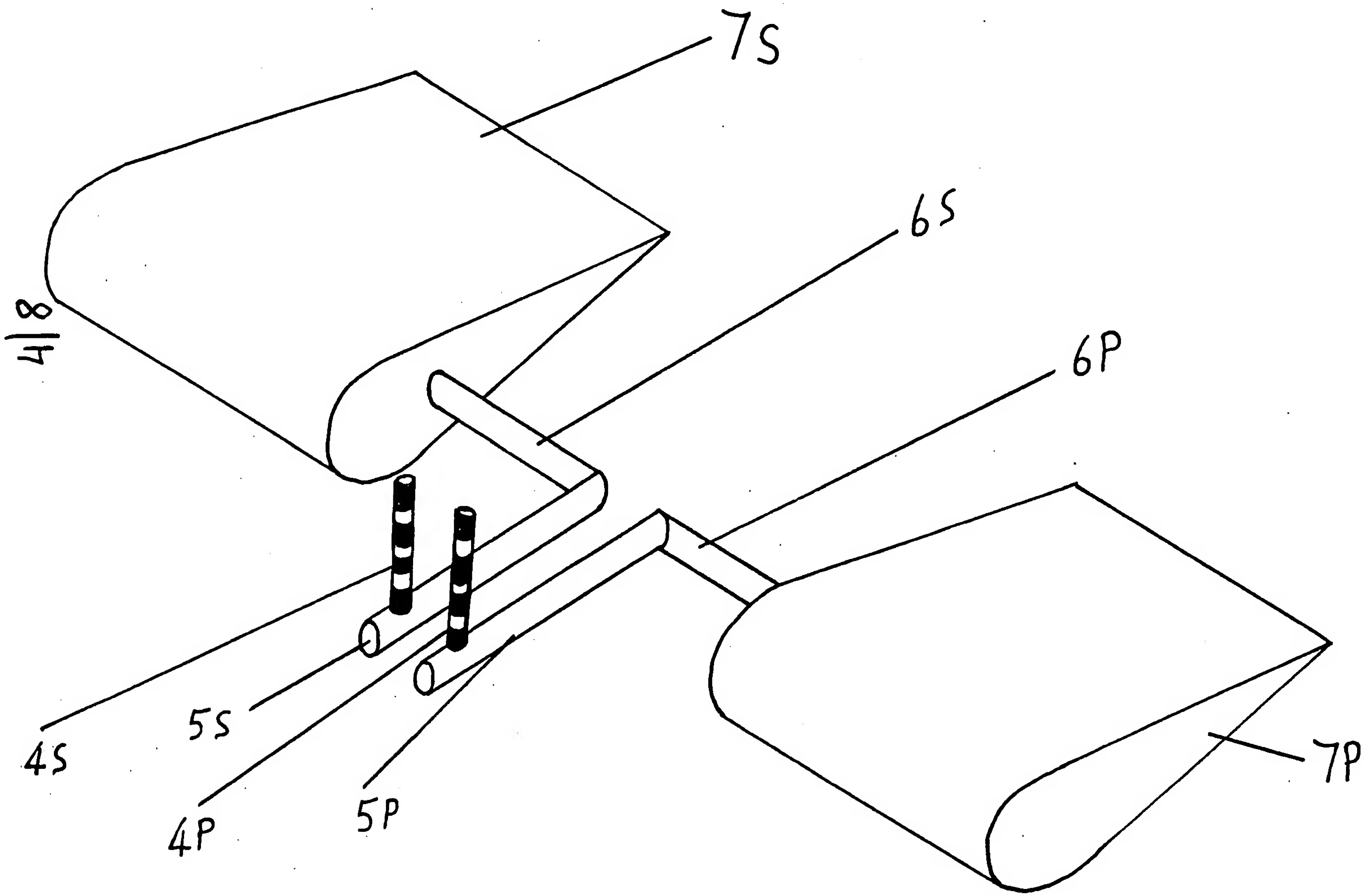

FIGURE V

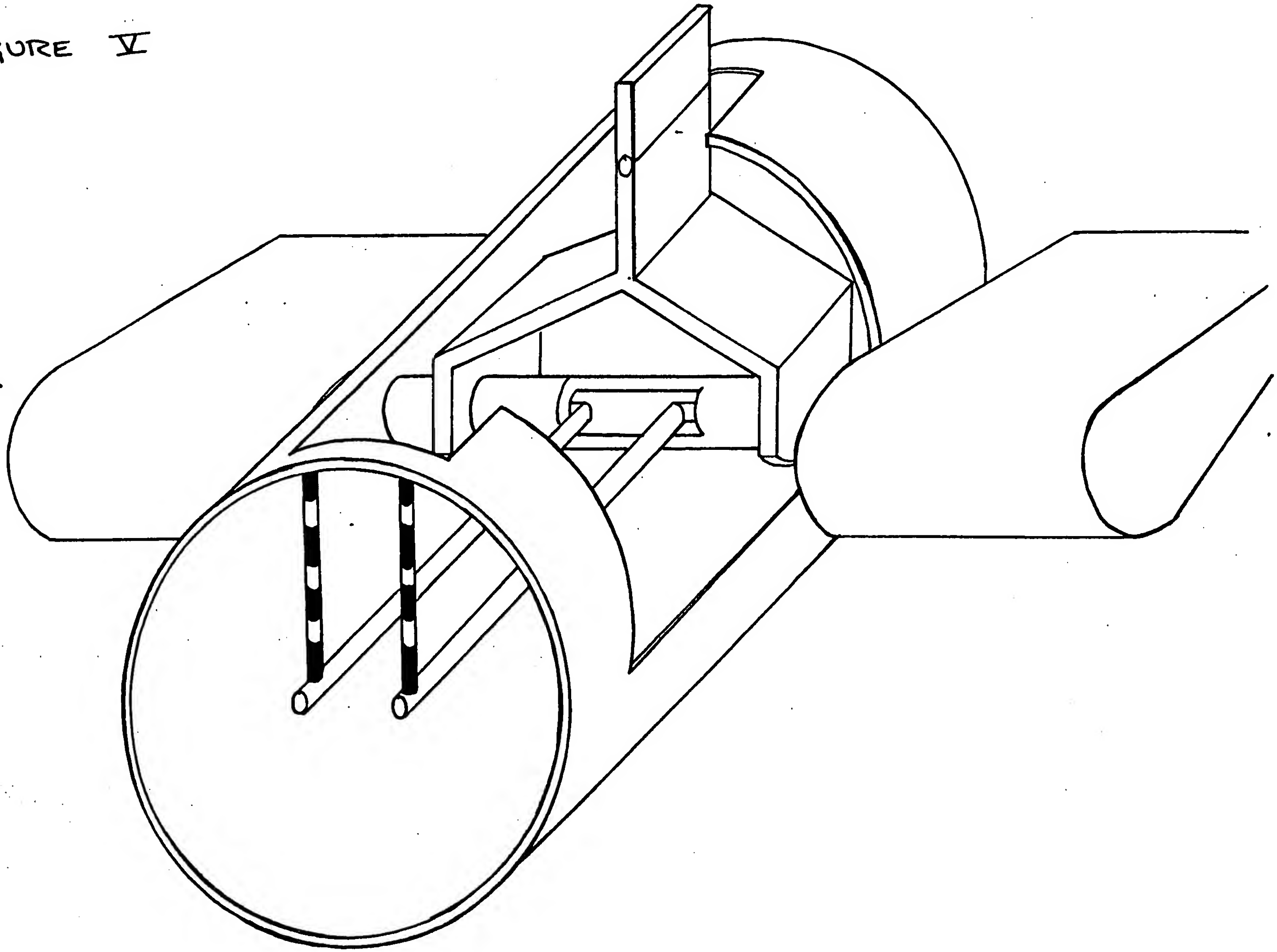

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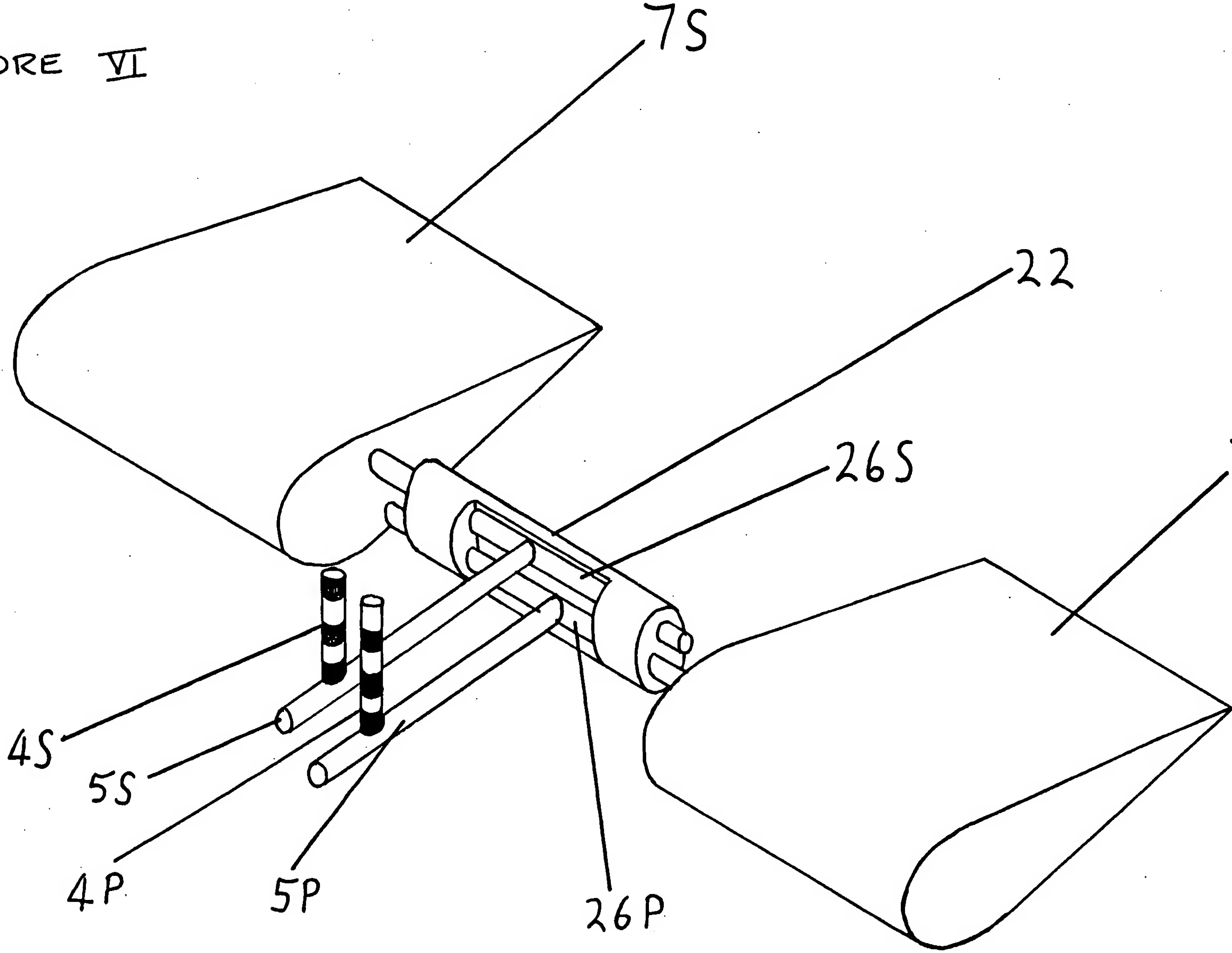
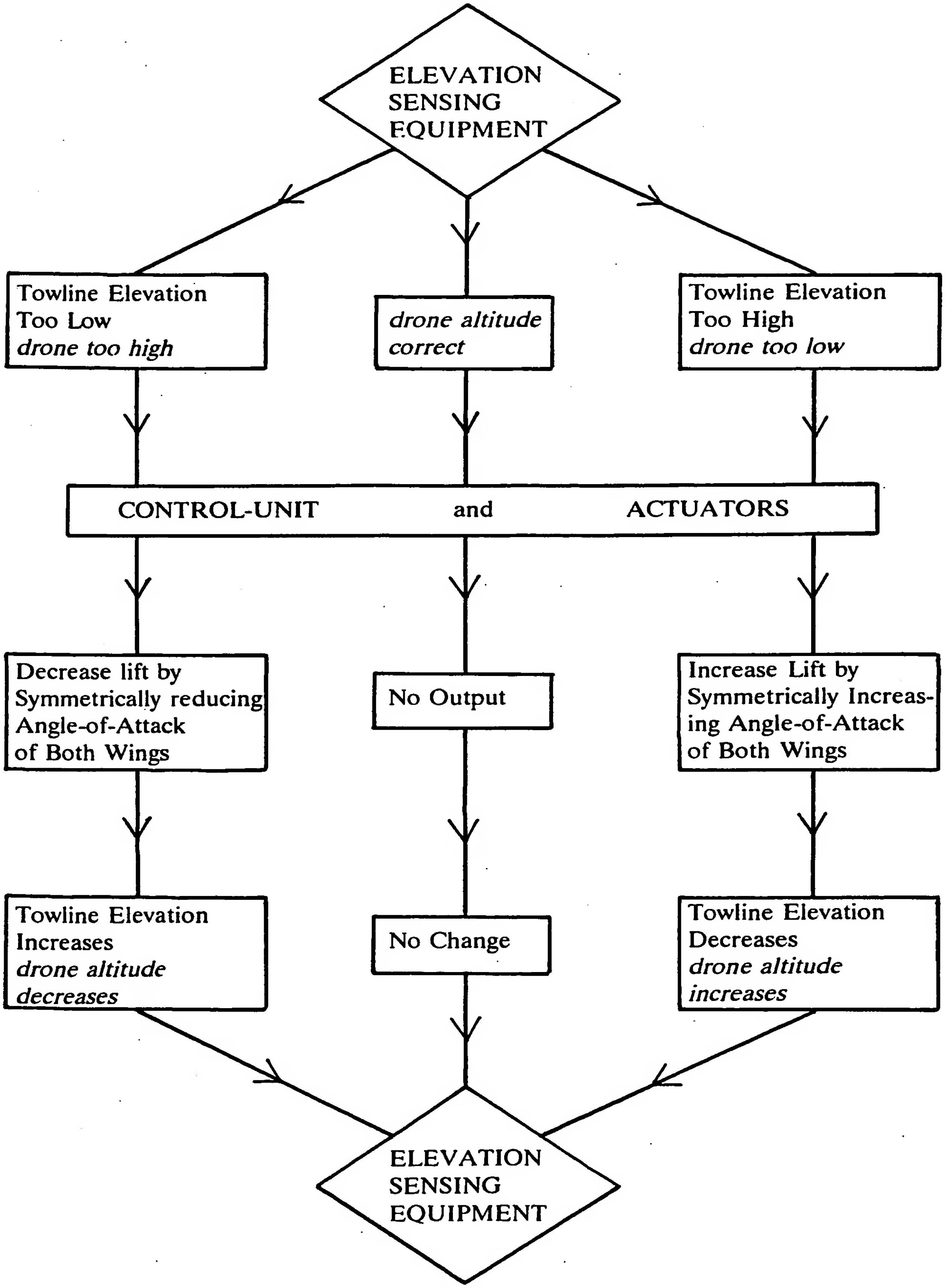
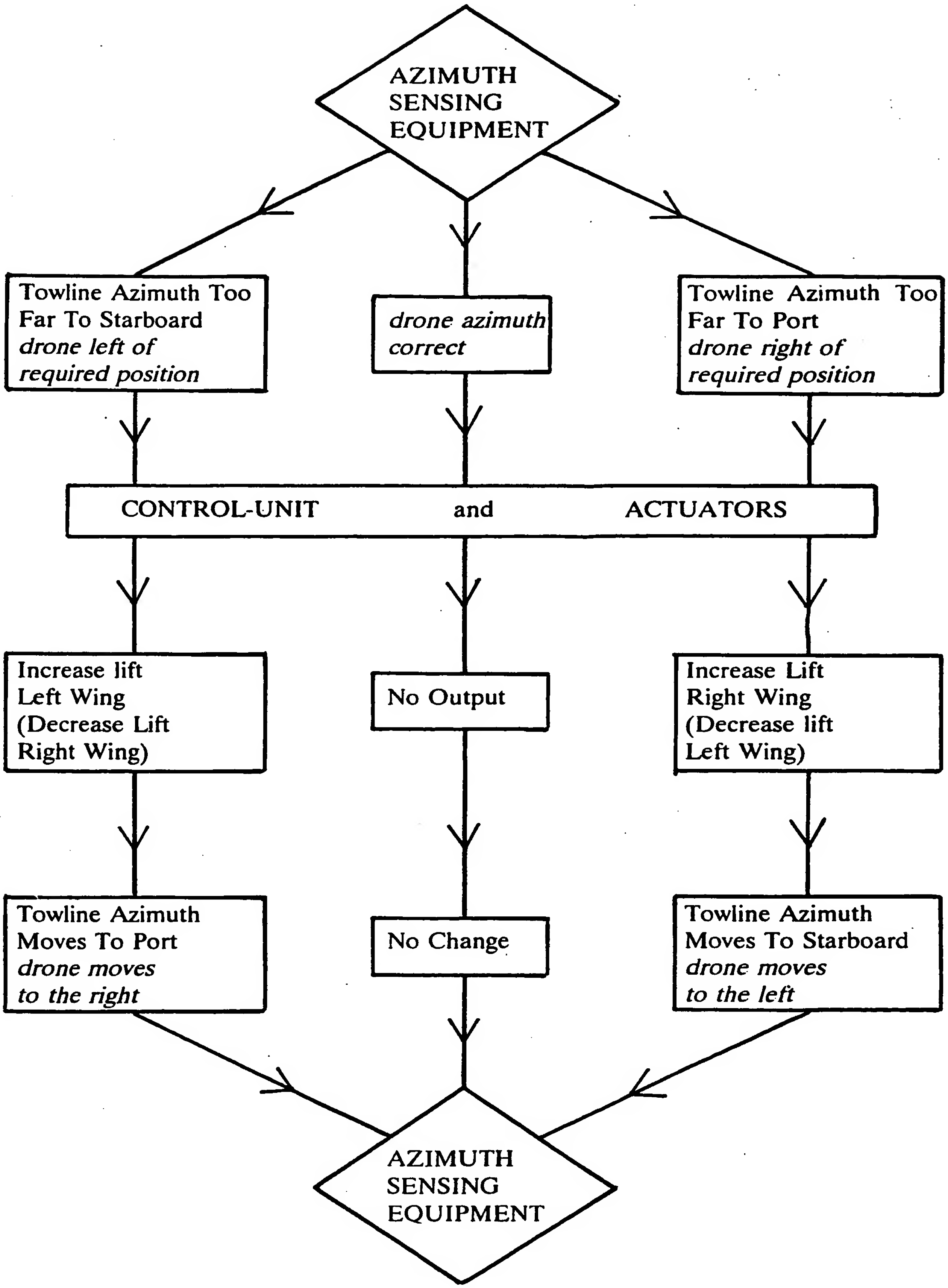
FIGURE VI



A LOGIC DIAGRAM OF THE ELEVATION CONTROL SYSTEM



A LOGIC DIAGRAM OF THE AZIMUTH CONTROL SYSTEM



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A DEVICE THAT CONTROLS THE AZIMUTH AND ELEVATION OF A TOWED OBJECT RELATIVE TO THE TOWING OBJECT

This invention relates to objects, hereafter referred to as drones, that may be towed on a flexible towline and are normally supported, in common with the tractor and towline, by the fluid medium through which they are travelling.

Drones are towed through air or water for purposes such as: being a moving target to be tracked or shot at; or perhaps for calibrating measuring equipment, by providing a known radar or optical cross-section at given distances from the measurer.

Generally, drones are supported and controlled simply by towline tension acting against fluid medium drag and gravity.

The present invention measures and resolves towline azimuth and elevation relative to the drone. These data are used, in real time, to control a pair of vanes, hereafter referred to as wings, that are attached to the drone. These controlled wings afford the operator significantly more control over the position of the drone, both vertically and horizontally, relative to the towline and tractor. Consequently the controlled flight envelope of the drone is considerably enlargened by this invention.

Furthermore, the improved control that is afforded to the drone enables a peculiar construction method to be employed which reduces bearing loads. This construction method also improves access to, and simplifies construction of, the apparatus inside the drone.

There are two aspects to the controlled flight that is afforded to the operator by this invention.

Firstly in elevation. (Primary method of control)

A universal-shackle, linking the towline to the drone, makes an angle with the longitudinal axis of the drone. This elevation angle is continuously measured by the control-unit. The control-unit is able to drive the elevation actuator which, by means of a mechanism, moves the wings, or lift devices, to increase [or decrease] the amount of lift generated by the wings. This causes the drone to climb [or descend] as the wings bear more [or less] of the weight of the drone that was hitherto supported by the towline [or the wings].

The operator can program the control-unit to control the drone to fly at any universal-shackle elevation relative to the drone, thereby controlling the altitude of the drone relative to the towline.

The control-unit accomplishes this task by means of a feed-back loop which continuously compares the actual elevation of the universal-shackle against the required elevation of the universal-shackle. If there is a discrepancy the control-unit drives the elevation actuator to move the wings, or lift devices, to alter the lift to adjust the drones altitude relative to the towline, thereby correcting the discrepancy.

Secondly in azimuth. (Primary method of control)

The universal-shackle, which links the towline to the drone, also makes an angle with the lateral axis of the drone. This azimuth angle is continuously measured by the control-unit. The control-unit is able to drive the azimuth actuator which, by means of a mechanism, moves the ailerons, or lift devices, which shifts the centre of pressure to port or starboard. This alters the rolling moment about the drones longitudinal axis and causes the drone to move laterally in the direction of the roll until there is equilibrium in that couple which exists between the moment of roll caused by the wings, or lift devices, and the moment of roll caused by any lateral component in the force exerted on the drone by the towline.

The operator can program the control-unit to control the drone to fly at any universal-shackle azimuth relative to the drone, thereby controlling the lateral displacement of the drone relative to the towline.

The control-unit accomplishes this task by means of a feed-back loop which continuously compares the actual azimuth of the universal-shackle against the required azimuth of the universal-shackle. If there is a discrepancy the control-unit drives the azimuth actuator to move the ailerons, or lift devices, which alters the rolling moment to adjust the drones lateral displacement relative to the towline, thereby correcting the discrepancy.

This controlled flight can be achieved by an alternative method.

Firstly in elevation. (Alternative method of control)

The universal-shackle, which links the towline to the drone, makes an angle with the longitudinal axis of the drone. This elevation angle is continuously measured by the control-unit. The control-unit is able to drive the actuators which, by means of their respective mechanisms, move the wings, or lift devices, symmetrically, to increase [or decrease] the angle of attack and, therefore, the lift generated by the wings. This causes the drone to climb [or descend] as the wings bear more [or less] of the weight of the drone that was hitherto supported by the towline [or the wings].

The operator can program the control-unit to control the drone to fly at any universal-shackle elevation relative to the drone, thereby controlling the altitude of the drone relative to the towline.

The control-unit accomplishes this task by means of a feed-back loop which continuously compares the actual elevation of the universal-shackle against the required elevation of the universal-shackle. If there is a discrepancy the control-unit drives the actuators to move the wings, or lift devices, which alters the lift to adjust the drones altitude relative to the towline, thereby correcting the discrepancy.

Secondly in azimuth. (Alternative method of control)

The universal-shackle, which links the towline to the drone, also makes an angle with the lateral axis of the drone. This azimuth angle is continuously measured by the control-unit. The control-unit is able to drive the actuators which, by means of their respective mechanisms, move the wings, or lift devices, asymmetrically, to shift the centre of pressure to port or starboard. This alters the rolling moment about the

drones longitudinal axis and causes the drone to move laterally in the direction of the roll until there is equilibrium in that couple which exists between the moment of roll caused by the wings, or lift devices, and the moment of roll caused by any lateral component in the force exerted on the drone by the towline.

The operator can program the control-unit to control the drone to fly at any universal-shackle azimuth relative to the drone, thereby controlling the lateral displacement of the drone relative to the towline.

The control-unit accomplishes this task by means of a feed-back loop which continuously compares the actual azimuth of the universal-shackle against the required azimuth of the universal-shackle. If there is a discrepancy the control-unit drives the actuators to move the wings, or lift devices, which alters the rolling moment to adjust the drones lateral displacement relative to the towline, thereby correcting the discrepancy.

The reasons for, and a description of, the peculiar construction method will now be set out. Note, this applies to the alternative method of control.

The number of moving parts, and therefore the degree of complication of construction, can be reduced if the wings are fixed to their respective spars and these spars are acted upon respectively by mechanisms which rotate the spars about the lateral axis to alter the wings angle of attack. If these spars occupy the same axis through the drone, and do not overlap, then, if they are the same lateral length, they will meet at the mid-point.

A method of construction which enables the spars to occupy different axes through the drone would, consequently, enable both spars to be longer, by, for example, half the width of the drone; assuming that both spars are supported across the entire width of the drone.

There are two advantages, and one disadvantage, to a construction method that enables the spars to occupy different axes:-

Advantage 1

The couple, about the bearings that support the spar, which occurs as a result of the forces acting on the wing, will be reduced by, for example, half; therefore the loads exerted on the bearings will be reduced by a similar amount.

Advantage 2

The manufacturer will enjoy improved access to apparatus that secures the spars laterally; and to that which acts upon the spars to rotate them, about their lateral axes.

Disadvantage

The movement of the pair of wings attached to the drone by this means will not be symmetrical at all times as the wings move to alter angle of attack. The effect of this asymmetry should not be noticed by the operator, as the control afforded by the whole invention shall more than compensate.

Three specific embodiments of this invention will now be described by way of example with reference to the accompanying drawings. Example 1 is an embodiment of the primary method of control. Example 2 is an embodiment of the alternative method of control, with spars occupying the same axis. Example 3 is an embodiment of the alternative method of control, with spars occupying different axes.

Figure I. Shows parts that are common to all examples.

Fixed inside the Chassis 1, (shown with a section cut away) is the Fulcrum-Bar 2. *In this drawing the Fulcrum-Bar 2, has one spar-axis; in figure VI, the Fulcrum-Bar 22, has two spar-axes.* The Universal-Shackle 10, is free to describe arcs about a lateral axis and an axis that is perpendicular to a line that is perpendicular to that lateral axis; these two arcs are indicated by arrows. The movement about these axes is measured by sensing equipment (not shown) and these measurements are used by the Control-Unit (not shown) to ascertain the elevation and azimuth of the towline relative to the drone. The Universal-Shackle 10, may be mounted on the Fulcrum-Bar 2, as shown, or it may be mounted directly onto the Chassis 1, or onto the drone itself. Furthermore, the Universal-Shackle may be mounted in such a way as to describe pairs of arcs about the following axes:- A longitudinal, or a normal, axis and an axis that is perpendicular to a line that is perpendicular to the aforementioned axis. Or: A lateral, or a longitudinal, or a normal, axis and an axis that is perpendicular to this aforementioned axis.

The drone into which this invention is incorporated is attached to the outside of the Chassis 1.

Figure II. Example 1

The Elevation Actuator 4, acts upon the Wings 7A, and 7B, by means of the Lever 5, acting upon the Spar 6. The Azimuth Actuator 3, acts upon the Ailerons 8A, and 8B, by means of Bowden Cables 9A, and 9B.

Figure III. Example 1

Shows a cut-away drawing of an assembly which incorporates the primary method of control.

Figure IV. Example 2

The Port Actuator 4P, acts upon the Port Wing 7P, by means of the Port Lever 5P, acting upon the Port Spar 6P. The Starboard Actuator 4S, acts upon the Starboard Wing 7S, by a similar mechanism.

Figure V. Example 2

Shows a cut-away drawing of an assembly which incorporates the alternative method of control.

Figure VI. Example 3

The Spars 26P, and 26S, may both be supported across the full lateral dimension of the Fulcrum-Bar 22. The Port Actuator 4P, acts upon the Port Wing 7P, by means of the Port Lever 5P, acting upon the Port Spar 26P. The Starboard Actuator 4S, acts upon the Starboard Wing 7S, by a similar mechanism.

CLAIMS

1, Equipment that measures towline azimuth and elevation relative to a drone and resolves these data in whole or in part for the purpose of controlling the size and direction of the lift force vector generated by the wings or vanes.

2, Equipment that measures towline elevation relative to a drone and resolves these data for the purpose of controlling the amount of lift force generated by the wings or vanes.

3, Equipment that measures towline azimuth relative to a drone and resolves these data for the purpose of controlling the rolling moment of lift force, about the drones longitudinal axis, generated by the wings or vanes.

4, Equipment as claimed in claims 1, and or claim 2, and or claim 3, that reduces the sum of the induced drag that is caused by the wings, or vanes, and the towline; by altering the ratio of lift generated by the wings, or vanes, to lift generated by the towline.

5, A system of logic such as the one illustrated on page 4.

6, A system of logic such as the one illustrated on page 5.

7, A system of logic as claimed in claim 5, and or claim 6, that utilises output from other equipment for the purpose of controlling the flight of a drone.

8, Equipment that facilitates the mounting and or movement of one, or more, spars and a towline attachment in the same axis.

9, Equipment that facilitates the mounting and or movement of two, or more, spars about respective and non-coincident lateral axes.

10, Equipment as claimed in claim 9, that enables a reduction of bearing loads in ratio with the increase in distance that is afforded between the bearings.

11, Equipment as claimed in claim 9, and or claim 10, that affords easier access to: apparatus that secures the spars laterally; and to apparatus which acts upon the spars to rotate them about a lateral axis.

12, Equipment and apparatus for controlling the course of a drone substantially as described herein with reference to and as illustrated in figures I to VI of the accompanying drawings.

Amendments to the claims have been filed as follows

1, Equipment that measures towline azimuth and elevation relative to a drone and resolves these data in whole or in part for the purpose of controlling the size and direction of the lift force vectors generated by the wings or vanes for the purpose of altering the ratio of lift generated by the wings to lift generated by the towline.

2, Equipment and apparatus for controlling the course of a drone substantially as described herein with reference to and as illustrated in figures I to V of the accompanying drawings.

The Patent Office

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Application No:	GB 9602332.0	**Examiner:**	C B VOSPER
Claims searched:	1-3 at least	**Date of search:**	14 May 1996

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): B7A(AAN), B7G(GCR), B7V(VHH,VHS), B7W(W49)

Int Cl (Ed.6): B63B 21/00,21/56,21/66; B63G 8/00,8/42; B64D 3/00,3/02; F41J 9/00,9/04,9/06,9/08,9/10

Other: ONLINE WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB2244249A	SOCIETE(figs 5-8; page 8, line 11 et seq.; page 10, line 15 et seq.)	1-3
A	GB1470356	DORNIER(page 2, lines 90 - 98 - lift control by computer)	1-3
X	GB0567887	C.B.PROJECTIONS (page 3, lines 41 to 69; Figs. 9,10; page 5, line 92 et seq.)	1-3
A	EP0387881A1	COMMONWEALTH (fig.1; col.5, lines 22 to 39)	2 at least
X	US5188313	PIASECKI (col.3, line 29 et seq.)	1-3
A	US3560912	SPINK (whole document)	1-3

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.